SUCCESSFUL ESTABLISHMENT OF THE ASIAN MUSSEL *Musculista senhousia* (BENSON IN CANTOR, 1842) IN NEW ZEALAND

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Abstract. The Asian marine mussel *Musculista senhousia* (Benson in Cantor) was accidentally introduced to New Zealand in the 1970s and by 1984 it had become well established in the Auckland Harbour area (Waitemata Harbour, Tamaki Estuary and Tamaki Strait). *M. senhousia* has also entered, and established in, ports of California and (recently) Western Australia. Shipping, rather than natural larval dispersal, appears to be the most probable agent of first introduction of four foreign bivalves into New Zealand within the last decade — *Theora lubrica* Gould, *Limaria orientalis* (A. Adams & Reeve), *Crassostrea gigas* (Thunberg), *Musculista senhousia* (Benson in Cantor). Once introduced, all four species spread rapidly. Concern is expressed at the ability of *M. senhousia* to form dense monospecific mats, so thick they dramatically alter the biota.

While in Auckland late in 1984, I visited Motukaraka Island in Tamaki Strait, where the intertidal biota is well known to me. I have visited there regularly between 1964 and 1980, and sampled there fortnightly from 1976 to 1979. Unexpectedly a species of mussel was found which had never been seen there previously. Subsequent visits to other beaches revealed this mussel was widespread and common throughout Auckland's Tamaki Strait, Tamaki Estuary and Waitemata Harbour.

The mussel was identified as an Asian species, *Musculista senhousia* (Benson in Cantor, 1842). This identification was based on Benson's (1842) description, Reeve's (1857) illustration, accounts by Kira (1962a, 1962b) and B. Morton (1974), and examination of shells in the Auckland Institute and Museum. There is no mention of *M. senhousia* in Powell's (1979) authoritative manual of the New Zealand Mollusca or Hickman's (1983) extensive bibliography of New Zealand marine mussels (1880-1982). In the molluscan collections at Auckland Museum there are four lots of *Musculista senhousia;* all are from Japan and the shells in each lot match the New Zealand material perfectly. Data for the Japanese lots is as follows: Japan — Finlay Collection (AM 27986); Nishikurobe, Ise, Japan — Brookes Collection (AM 32252); Ise, Japan — Brookes collection (AM 32254); Tamioka, Tokyo Bay, Japan — Leg. Thaanum 1940 (AM 24478). Subsequently the identification of *M. senhousia* was confirmed by Dr B.R. Wilson of Melbourne. Voucher specimens of *M. senhousia* from New Zealand have been deposited in the Auckland Institute and Museum, Museum of Victoria Melbourne, Australian Museum Sydney, and Western Australia Museum Perth.

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Besides documenting the arrival of this exotic bivalve in New Zealand, this paper considers its taxonomy, biology and method of introduction.

Family MYTILIDAE

Genus **Musculista** Yamamoto & Habe, 1958

Musculista Yamamoto & Habe, 1958. Bull.Mar.Biol.Stn. Asamushi, Tohoku Univ.: 9. Type-species, by O.D., *Modiola senhousia* Benson in Cantor, 1842. Recent, western Pacific Ocean.

Musculista senhousia (Benson in Cantor, 1842) (Figs. 1-3)

1842. *Modiola senhousia* Benson in Cantor, Ann. Mag. Nat. Hist. 9: 489.
1857. *Modiola senhausii* (sic) Reeve, *Modiola* pl. 5, species 22.
1874. *Modiola bellardiana* Tapparone-Canefri, Malac. Zool. "Magenta" 144, pl. 4, figs. 1b, 4, 4a.
1944. *Volsella senhausi* (sic) (Reeve): A. G. Smith, Min. Coach. Club S. Calif. 39: 18.
1958. *Musculus (Musculista) senhousia* (Benson in Cantor): Yamamoto & Habe, Bull. Mar. Biol. Stn. Asamushi, Tohoku Univ.: 9, pl. 2, fig. 13.
1959. *Brachidontes (Arcuatula) senhousia* (Benson in Cantor): Kira, Col. Illus. Shells Japan: 114, pl. 45, figs 1a, 1b.
1962. *Brachidontes (Musculista) senhousia* (Benson in Cantor): Kira, Col. Illus. Shells Japan: 114, pl. 45, figs 1a, 1b.
1966. *Modiolus senhousei* (sic) (Benson in Cantor): Hanna, Occas. Pap. Calif. Acad. Sci. 48: 59, fig. 67.
1974. *Musculista senhausia* (sic) (Benson in Cantor): B. Morton, Pacific Sci. 28: 19-33.

Benson (1842) in an addendum to Cantor's long paper on Chusan Island, originally spelt the specific name *"Senhousia"* and, although the spelling *senhousei* would strictly have been the correct patronym from the surname Senhouse, as Hanna (1966) noted, there is no evidence in the original publication a spelling mistake had occurred or that Benson intended the name should be written otherwise. Accordingly all subsequent combinations (i.e., *senhausi, senhausii, senhusi, senhousea, senhousei*) must be treated as incorrect subsequent spellings and therefore invalid (I.C.Z.N. 1961, Article 32 (a)). In fact the International Code specifically states that incorrect transliteration and improper latinisation are not to be considered inadvertent errors.

Musculista senhousia was originally placed in the genus *Modiola* but Benson (1842) did not provide an illustration to accompany his description. Reeve (1857), however, included an excellent coloured figure and commented: "An extremely delicate species, most beautifully sculptured and coloured." Yamamoto & Habe (1958) introduced the name *Musculista* (as a subgenus of *Musculus*) with *M. senhousia* as type-species. *Musculista* was differentiated by its thin shell with radially-ribbed antero-ventral section and smooth central and posterior sections. Kira (1962b) followed Yamamoto & Habe and used *Musculista* as a subgenus of *Musculus* Röding. Kira (1962a) placed it as a subgenus of *Brachidontes* Swainson. Most recent authors have given *Musculista* full generic status. I follow this practice on the advice of Dr Wilson who informs me that, in his opinion, *Musculista, Brachidontes* and *Musculus* are not congeneric and the former two do not even belong in the same subfamily of the Mytilidae (Wilson pers. comm.).

The shells figured as *Musculus senhousia* by Abbot & Dance (1982) are misidentified. They appear, by their elongate shape, to be *Musculista japonica* (Dunker).

Figs. 1-2. *Musculista senhousia* (Benson in Cantor). 1. Left valve from Motukaraka Island, Tamaki Strait, Auckland, 23.2 mm. 2. Left valve from Ngataringa Bay, Waitemata Harbour, Auckland, 21 mm.

Description

Shell (Figs. 1,2) maximum length 29 mm. Shape elongate to elongate-ovate; anterior end normally rounded; dorsal margin straight, reaching a height above that of umbones; posterior end flaring, broadly rounded; ventral margin straight or weakly concave; margins completely smooth except anterior one which is indistinctly crenulate. Shell very thin, equivalve, cylindrical, considerably inflated centrally, yet compressed posteriorly when viewed from above. Umbones small, subterminal (approximately one-tenth distance back from anterior end), prosogyrate. Ligament internal, opisthodetic, elongate and thin, deeply set on weak nymphs; resilium entire. Hinge edentulous (i.e., without true teeth) but with dysodont teeth before and behind ligament. Inner margin of anterior dorsal end with 6 to 10 small teeth close to the umbo; entire dorsal margin bearing small oblique teeth — 32 to 36 weaker ones above ligament and 9 to 11 stronger ones behind ligament; teeth alternate between valves and interlock when valves close.

Exterior smooth except for 6 to 10 broad radial ridges (obsolete in some shells) at anterior end extending from umbo to margin; rest of shell with fine, close concentric growth striae and occasional strong concentric ridges representing successive growth phases. Scars of adductor and retractor muscles and pallial line hardly discernible. Exterior covered uniformly by a thin, translucent, olive-green, smooth periostracum; marked with a series of irregular, undulating, concentric, purplish-brown zig-zags that become straight near the dorsal margin and are crossed, on the dorsal slope, by many, narrow, uninterrupted, reddish radial lines. Interior with a thin nacre, but highly lustrous nevertheless; creamish, barred throughout with purplish-red wavy lines and often (particularly in adults) stained with a large, violet blotch centrally.

Animal (Fig. 3) with anterior adductor elongate, narrow, situated close to mantle margin at anteroventral floor of shell valves. Posterior adductor rather large, ovate; located close to shell's dorsal margin posteriorly; conspicuously divided into equal smooth and striated portions that meet at an oblique junction. Pedal and byssal retractor muscles as in *Modiolus*. Anterior pedal retractors well developed but rather small, elongate, inserted close to margin at anterior end immediately below umbones. Posterior byssal retractors very large, elongate, attached to shell immediately above posterior adductors which they touch. Posterior pedal retractors large (but relatively smaller than posterior byssal retractors); attached directly in front of posterior byssal retractors (from which they are separated by a very small gap posteriorly); extending below pericardium to middle of shell. Anteriorly those two sets of retractors arise contiguously at origin of foot/byssus complex. Siphonal retractor muscle originates from lower posterior section of posterior adductor, runs (as a very thin strand) obliquely, lying against mantle and inserts at base of siphonal area of inner mantle fold. Foot relatively elongate and narrow; ventral surface with a longitudinal byssal gland groove; tip flattened dorsoventrally and rounded; colour cream, lightly suffused with superficial brown pigment dorsally and ventrally.

All three mantle lobes smooth; not fused along ventral margin from the anterior sixth of animal's length (where inner folds fuse) just behind anterior adductor muscle to extreme posterior end where inner lobes again fuse at base of exhalent opening. No indication whatsoever of fusion or increased muscularisation of mantle lobes around inhalent opening (as would constitute an inhalent siphon). Posteriorly, in area of inhalent opening, the inner mantle lobe bears a series of compound papillae; mantle and papillae chocolate brown with small, irregular areas of intense white pigment; large vertical branchial septum present within inhalent aperture. Exhalent siphon with a thin-walled complete margin; slightly elevated above inner mantle lobe; two thin valves block siphonal aperture from within, dorsal flap being closer to aperture, gap between them a narrow transverse slit.

Ctenidia large (extending full length of mantle cavity); filibranchiate, homorhabdic. In each gill, descending lamellae are a little longer than ascending ones — descending lamellae of outer demibranch being largest of all. Ascending lamellae of outer demibranch not fused with mantle but those of inner demibranch connected by ciliary junction to visceral mass. Labial palps large, elongate (reaching level with anterior edge of foot/byssus complex when extended posteriorly, i.e., about one-third length of mantle cavity), relatively narrow; inner faces strongly vertically plicate. Renal and genital apertures on separate papillae that open contiguously on roof of mantle cavity two-thirds of way back, just in front of level of anterior end of posterior adductor muscle.

Sexes separate. Gonadial tubules lie dorsally over digestive gland at anterior half of body in front of pericardium and invest most of mantle walls. No mesosoma in midline behind foot/byssal complex.

B. Morton (1974) has described the ciliary currents of the mantle, visceral mass and foot as well as the structure of the organs of the alimentary canal. *Musculista senhousia* is unique amongst mytilids hitherto examined in having the style sac

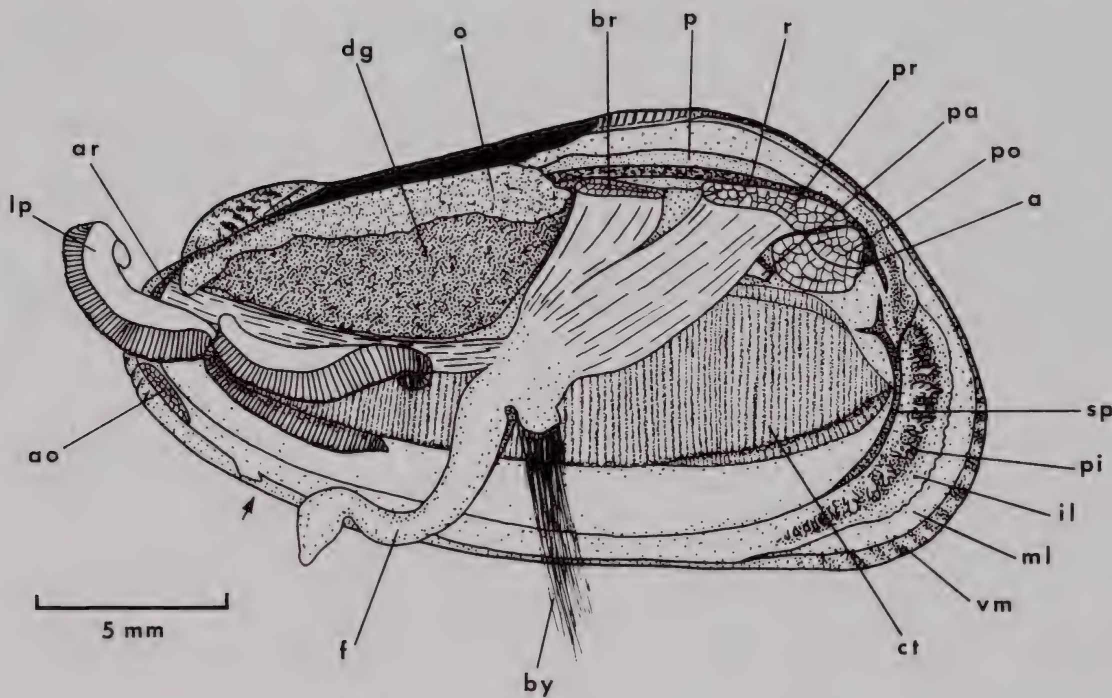

Fig. 3. *Musculista senhousia* (Benson in Cantor). Anatomy of the mantle cavity from the left side; left valve, mantle lobe and ctenidium removed. Arrow at front indicates point of separation of inner mantle lobes. Abbreviations: a, anus; ao, anterior adductor muscle; ar, anterior pedal retractor muscle; br, byssal retractor muscle; by, byssus; ct, (inner demibranch of) ctenidium; dg, digestive gland; f, foot; il, inner lobe of mantle; lp (outer) labial palp; ml, middle lobe of mantle; o, ovary; p, pericardium; pa, excretory and genital papillae; pi, papillae on (exhalent area of) inner mantle lobe; po, posterior adductor muscle; pr, posterior pedal retractor muscle; r, rectum; sp, septum; vm, valve margin.

separated from the midgut. Ieyama (1977) has described the karyotype of *M. senhousia,* for which the diploid chromosome number is 30 and the haploid number is 15.

A juvenile pinnothereid crab, probably *Pinnotheres novaezelandiae* Filhol, was living in the mantle cavity of one specimen of *Musculista senhousia* that I dissected.

Ecology and distribution

Musculista senhousia is widely distributed in eastern Asia where it occurs naturally from Singapore to the Siberian coast (Chuang 1961; Kikuchi & Tanaka 1978). Its abundance throughout this range has facilitated numerous ecological studies and these have been summarised by Kikuchi & Tanaka (1978). Briefly, B. Morton (1974) recognised discrete age classes within a population in Tai Tam Bay, Hong Kong; maximum density at this site was 2500 per m^2. Kikuchi & Tanaka (1978) found *M.*

senhousia not only to share numerical dominance with *Theora lubrica* (with maximum density of *M. senhousia* about 750 per m^2) but also to be "overwhelmingly dominant" in terms of biomass (accounting for 42-94% of total biomass) within Tomoe Cove, Tamioka Bay, Amakusa Shimoshima Island on the west coast of Kyushu Island, Japan. In the same year, these authors published further studies on productivity of *M. senhousia* in Tomoe Bay (Tanaka & Kikuchi 1978). In 1978 also, Kulikova described the morphology, seasonal population dynamics and settlement of larvae in the Brusse Lagoon, Aniva Bay, Sea of Okhotsk, Russia (Kulikova 1978). Larvae were numerous in the plankton of the lagoon during the months of highest sea temperatures with a maximum density of 17000 per m^3 and spat settled in greater numbers than any other bivalve.

Several common themes emerge from these ecological studies on *Musculista senhousia.* One is the mussel's considerable fecundity which, together with its gregarious habit, leads to high population densities being attained. Others are the rapid growth rate and the tendency for populations to fluctuate widely and unpredictably in time; in some years there are enormous populations at particular localities but in others *M. senhousia* can be completely absent. Both B. Morton (1974) and Kikuchi & Tanaka (1978) documented the complete disappearance of their entire study populations within a few months. The latter workers suggested the disappearance could have been caused by severe oxygen depletion in bottom waters that resulted from summer stratification.

Observations on *Musculista senhousia* in New Zealand indicate two apparently contradictory facets of its behaviour ("nest" building). On low sandstone reefs, which are uncovered at low tide, individuals were found amongst the algae *Hormosira banksii* and *Corallina officinalis,* and invariably alongside the small colonial mussel *Xenostrobus pulex.* Each was stayed in a near-vertical orientation by its byssus, nestling amongst the *Corallina* algal turf or within the extensive beds of *Xenostrobus.* On the sides and floor of silty pools individuals were living side by side, completely surrounded by a continuous weft ("nest") of interwoven byssal threads, tiny shell fragments and entrapped silt. Previous accounts have indicated that *Musculista senhousia* was sometimes found with (Kira 1962b; B. Morton 1974; Kikuchi & Tanaka 1978) or sometimes without (Hanna 1966) a byssal "nest". Obviously this mussel is flexible as regards formation of a "nest"; one is produced when required (as in silty pools or on soft substrates) but no "nest" is made when *M. senhousia* lives on hard substrates where it is in company with other clustering organisms or amongst dense algal turfs. There is no doubt that this species lives in two different habitats.

In December 1984 and January 1985 many beaches on Auckland's east coast were checked for *Musculista senhousia.* More dead shells than live specimens were present as indicated in Table 1. There was not time to search subtidally for this mussel.

Detailed investigations were made on the density of *Musculista senhousia* at one locality at which it had been observed as being maximally abundant, i.e., Motukaraka Island. There, on January 4, 1985, three 1 m^2 quadrats were searched exhaustively to get an exact measure of the mussel's numbers. All three quadrats were on the extensive intertidal reef platform on the northeastern side of the island (see Willan 1979 for a description of the locality) and each was deliberately selected as being within

Table 1. Localities and abundance of *M. senhousia.*

Locality	Abundance	Remarks
Matakatia Bay (southern end), Whangaparaoa Peninsula	Rare	1 live and 2 dead shells.
Castor Bay, lower Auckland Harbour	Absent	
Marine Parade, Devonport, lower Auckland Harbour	Absent	
Ngataringa Bay (southern end) lower Auckland Harbour	Rare	Many dead shells.
Farm Cove Yacht Club Shore, Tamaki Estuary	Common	Many dead shells.
Eastern Beach, near Howick, Tamaki Strait	Rare	Several dead shells
Howick Beach (northern end), Tamaki Strait	Common	Many dead shells.
Mellons Bay, Tamaki Strait	Abundant	Many dead shells.
Cockle Bay, Tamaki Strait	Absent	1 dead shell only.
Shelly Bay (northern end), Tamaki Strait	Absent	
Motukaraka Island, Tamaki Strait	Abundant	Many dead shells.
Puriri Bay (western end), Beachlands, Tamaki Strait	Rare	Few dead shells.

Abundant = more than 50 live specimens observed during 30 minutes searching in suitable habitats. Common = 10 to 40 live specimens observed during 30 minutes searching in suitable habitats. Rare = less than 10 live specimens found during entire search.

an area of maximum *M. senhousia* density. Besides recording the number of live *M. senhousia* in each quadrat, counts of the other two co-occuring mytilids, *Xenostrobus pulex* (Lamarck) the little black mussel and *Perna canaliculus* (Gmelin) the green-lipped mussel were also made. Results are presented in Table 2.

Table 2. Numbers of mytilids at Motukaraka Island.

	Quadrat 1	Quadrat 2	Quadrat 3
Musculista senhousia	10	6	2
Xenostrobus pulex	2800	4500	3600
Perna canaliculus	27	29	97

The figures in Table 2 demonstrate that, in early 1985, *Musculista senhousia* was living at a density of 6 per m^2, which was almost eight times less common than *Perna canaliculus* (all of which incidentally, were juveniles less than 40 mm in length) and very approximately four hundred and fifty times less common than *Xenostrobus pulex.* Dead shells of *M. senhousia* were much commoner than living specimens, the mean density of those being 59 per m^2. Because of their fragility, it is probable that dead valves of *M. senhousia* are never transported more than a few metres from the site where the animal lived before they disintegrate. Probably subtidal surveys or counts of specimens in "nests" on soft substrates would have yielded much higher densities in localised patches.

At present, this density recorded for one New Zealand population is well below the maximum, or at least that which *Musculista senhousia* has been found to be capable of in Asian waters. B. Morton (1974) reported numbers of up to 2500 per m^2 in Hong Kong.

No juvenile or subadult specimens (i.e., individuals with shells less than 15 mm long) were found live on this survey. All the living specimens collected proved, on dissection, to be sexually mature adults. This observation indicates the entire population at Motukaraka Island represented a single age class.

It is not known exactly how and when *Musculista senhousia* was introduced into Auckland. Professor J.E. Morton discovered two live specimens on the narrow intertidal reef platform at the front of the road at Black Reef, Westmere, upper Auckland Harbour in May 1980. Mr N. Douglas has a fresh, whole shell in his collection which was found at Puru, Thames by Mesdames M. and D. Bramley in November 1980. Because of the small number of specimens that these first records are based on, it seems likely *M. senhousia* arrived in New Zealand in the mid to late 1970s. However the considerable distance between Auckland Harbour and Thames indicates *M. senhousia* had already spread throughout Tamaki Strait by 1980. Shells collected by some vigilant Auckland conchologists since 1980 document its establishment and rapid dispersal. Mrs M. Morley found several specimens in the Tamaki Estuary (on the shore off Fisher Parade) on 14 August 1982. Mrs C. McLoughlin found many specimens at Omana Beach, near Maraetai, Tamaki Strait on 28 August 1983. Mr D. Snook observed large numbers washed ashore at Little Bay, Kaiaua, north of Miranda, Thames after a northerly storm on 25 February 1984. Mrs P. Town found several specimens washed up at Miranda, Thames in November 1984. As this paper was being written, I received advice from Mrs M. Morley in Auckland that she had located "hundreds of *Musculista senhousia* alive in thick matted beds covered with silt and quite invisible" near the yacht club between Little Bucklands and Bucklands Beach in Tamaki Estuary.

There are no known collections of *M.senhousia* from the Manukau Harbour, west of Auckland, and the present limits of distribution in New Zealand are unknown.

Musculista senhousia has also successfully invaded other parts of the world. It was first reported in California in 1944 (A.G. Smith 1944) and is now well established there (Hanna 1966). It is apparently still spreading and has recently colonised San Diego Harbour (B. Wilson pers. comm.). Kincaid (1947) found *M. senhousia* in abundance at Puget Sound, Washington. In January 1983 came the discovery of a population in the Swan Estuary, Perth, Western Australia by Mrs A. Brearley. Two of the other bivalves introduced to New Zealand, *Crassostrea gigas* and *Theora lubrica,* have also become established in California (Hanna 1966; Seapy 1974).

Discussion

Four species of exotic bivalves have recently arrived in, and spread rapidly between, New Zealand harbours (particularly northern North Island); they are *Theora lubrica* Gould, *Limaria orientalis* (A. Adams & Reeve), *Crassostrea gigas* Thunberg (Powell 1976) and *Musculista senhousia* (Benson in Cantor). Because of the sites of presumed first introduction (i.e., collection), rapidity of dispersal, and magnitude of their populations, this kind of establishment of new species in New Zealand is quite different from the gradual arrival of foreigners as larvae with oceanic currents from the northwest. This latter process has resulted in the introduction of many temperate and subtropical eastern Australian species into northern New Zealand coastal waters; some have established (Powell 1976) and many must have perished. This natural process has probably operated throughout the Tertiary (at least) and resulted in the influxes of many species during periods of increased sea temperatures. However another method of arrival must be invoked for the bivalves in question (and several other exotic invertebrates, see Dromgoole & Foster 1983). In these cases, the evidence points overwhelmingly to their accidental introduction by shipping from Japanese ports. *Crassostrea gigas* is perhaps an exception; it may have been imported deliberately (Dromgoole & Foster 1983). Exactly how such introductions occur (i.e., attached to vessel's hulls or in ballast water) is uncertain but the number of invading species, their first establishment in harbours and their simultaneous arrival in ports of other countries around the world makes an hypothesis of establishment by natural larval dispersal (e.g., Climo 1976; Beu 1977) highly doubtful for these particular species. It is in fact, difficult to conceive the arrival of these species as anything but man-aided.

There is also other evidence supporting the argument for introduction by shipping, and specifically shipping from Japan. Data on shipping movements in Auckland Harbour given by Droomgoole & Foster (1983) show there was a marked increase between 1970 and 1979 in the number of vessels for which Auckland was the first port of call after a direct run from a Japanese port. Records indicate the establishment in Auckland during the same period and since, of no less than six additional marine invading organisms, both plants and animals, that were previously known from Japan: the algae *Codium fragile tomentosoides* (Van Goor) Silva and *Colpomenia bullosa* (Saunders) Yamada, the actiniarian *Sagartia luciae* Verrill, the brachyuran *Pyromaia tuberculata* (Lockington) and the nudibranchs *Okenia plana* Baba and *Thecacera pennigera* (Montagu) (Dromgoole 1975; Willan 1976; Parsons 1982; Dromgoole & Foster 1983; Willan & Coleman 1984). The arrival of a "cargo" of Japanese organisms (particularly barnacles) into New Zealand has also been recorded (Foster & Willan 1979), though the vessel was unconventional — an enormous floating oil platform.

A prerequisite for any colonising species is that it be opportunistic. *Musculista senhousia* possesses many attributes, notably its fast growth rate and high reproductive capacity (B. Morton 1974), that warrant its classification as an opportunist. Besides these properties, is the unique ability of this mussel to colonise both hard and soft substrates. Dr B. Morton has vividly described this process and its consequences. When colonising soft substrates, *M. senhousia* weaves its byssal threads into an all-enclosing protective "nest". This behaviour enables it to build up dense sheets with numbers of up to 2500 per m^2 on sand flats. Under such circumstances the colony rapidly changes the habitat into a mud flat through the stabilisation of the sand grains by byssal "nests" together with copious production of mucous-bound faeces and pseudofaeces. Deep-living infaunal species such as bivalves are excluded from these newly-formed mud flats because they cannot project their siphons through the compacted mussel colony to reach the water above. Thus there is a drastic alteration in the local fauna.

All the harbours of the northern North Island possess extensive sand flats which appear conducive to mat formation by *Musculista senhousia,* so its presence in New Zealand should be viewed with concern.

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REFERENCES

ABBOT, R. T., and S. P. DANCE
1982 *Compendium of Seashells.* New York. 411p.

BENSON, W. H.
1842 Mollusca. Pp. 486-490, Addendum no. 5 to T. Cantor. General features of Chusan with remarks on the flora and fauna of that island. *Ann. Mag. Nat. Hist.* 9: 265-278; 361-370; 481-493.

BEU, A. G.
1977 Fossil History of *Limaria orientalis* in New Zealand. *Auckland Mus. Conch. Sec. Bull. (New Series)* 2: 1-7.

CHUANG, S. H.
1961 *On Malayan Shores.* Singapore. 225p.

CLIMO, F. M.
1976 The occurrence of *Theora (Endopleura) lubrica* Gould, 1861 (Mollusca: Bivalvia: Semelidae) in New Zealand. *Auckland Mus. Conch. Sec. Bull. (N.S.)* 1: 11-16.

DROMGOOLE, F. I.
1975 Occurence of *Codium fragile* subspecies *tomentosoides* in New Zealand waters. *N.Z. J. Mar. Freshwater Res.* 9: 257-264.

DROMGOOLE, F. I., and B. A. FOSTER
1983 Changes to the marine biota of the Auckland Harbour. *Tane* 29: 79-96.

FOSTER, B. A., and R. C. WILLAN
1979 Foreign barnacles transported to New Zealand by an oil platform. *N.Z. J. Mar. Freshwater Res.* 13: 143-149.

HABE, T.
1977 *Systematics of Mollusca in Japan: Bivalvia and Scaphopoda.* Tokyo. 372p.

HANNA, G. D.
1966 Introduced mollusks of western North America. *Occas. Pap. Calif. Acad. Sci.* 48: 1-108.

HICKMAN, R. W.
1983 An annotated bibliography of New Zealand marine mussels (Mytilidae), 1880-1982. *Occas. Publ. Fish. Res. Div.* (New Zealand) 40: 1-44.

IEYAMA, H.
1977 Studies on the chromosomes of two species of Mytilidae (Pteriomorphia, Bivalvia). *Venus JPN. J. Malacol.* 36: 25-28.

INTERNATIONAL COMMISSION ON ZOOLOGICAL NOMENCLATURE
1961 *International Code of Zoological Nomenclature adopted by the XV International Congress of Zoology.* London. 176p.

KIKUCHI, T., and M. TANAKA
1978 Ecological studies on benthic macrofauna in Tomoe Cove, Amakusa I. Community structure and seasonal change of biomass. *Publ. Amakusa Mar. Biol. Lab. Kyushu Univ.* 4: 189-213.

KINCAID, T.
1947 The acclimatization of marine animals in Pacific northwest waters. *Minutes Conch. Club Southern Calif.* 72: 1-3.

KIRA. T.
1962a *Coloured Illustrations of The Shells of Japan. Enlarged and Revised Edition.* Osaka. 239p.
1962b *Shells of the Western Pacific in Colour.* Osaka. 224p.

KULIKOVA, V. A.
1978 Morphology, seasonal population dynamics and settlement of larvae of the lamellibranch *Musculista senhousia* in the Busse Lagoon (South Sakhalin). *Biol. Morya. Vladivostok.* 4: 61-66.

MORTON, B.
1974 Some aspects of the biology, population dynamics, and functional morphology of *Musculista senhausia* Benson (Bivalvia, Mytilidae). *Pacific Sci.* 28: 19-33.

PARSONS, M.
1982 *Colpomenia* (Endlicher) Derbès et Solier (Phaeophyta) in New Zealand. *N.Z. J. Bot.* 20: 289-301.

POWELL, A. W. B.
1976 On the considerable influx of warm water molluscs that have invaded northern New Zealand waters within recent years. *Rec. Auckland Inst. Mus.* 13: 141-166.
1979 *New Zealand Mollusca: Marine, Land and Freshwater Shells.* Auckland. 500p.

REEVE, L.
1857 *Conchologia Iconica 10; No. 11 Monograph of the genus Modiola.* London. pp. 1-11.

SEAPY, R. R.
1974 The introduced semelid bivalve *Theora (Endopleura) lubrica* in bays of southern California. *Veliger.* 16: 385-387.

SMITH, A. G.
1944 *Volsella senhausi* Reeve in Bolinas Bay, California. *Minutes Conch. Club Southern Calif.* 39:18.

TANAKA, M., and T. KIKUCHI
1978 Ecological studies on benthic macrofauna in Tomoe Cove, Amakusa I. Production of *Musculista senhousia (Bivalvia, Mytilidae). Publ. Amakusa Mar. Biol. Lab. Kyushu Univ.* 4: 215-233.

WILLAN, R. C.
1976 The opisthobranch *Thecacera pennigera* (Montagu) in New Zealand with a discussion on the genus. *Veliger* 18: 347-352.
1979 *The Ecology of two New Zealand opisthobranch molluscs.* Unpubl. PhD thesis, University of Auckland. 278p.

WILLAN, R. C., and N. COLEMAN
1984 *Nudibranchs of Australasia.* Sydney. 56p.

YAMAMOTO, G., and T. HABE
1958 Fauna of shell-bearing mollusks in Mutsu Bay. Lamellibranchiata (1). *Bull. Mar. Biol. Stn Asamushi, Tohoku Univ.* 9(1): 1-20.